

Understanding Drainage Equations

Greg Larson

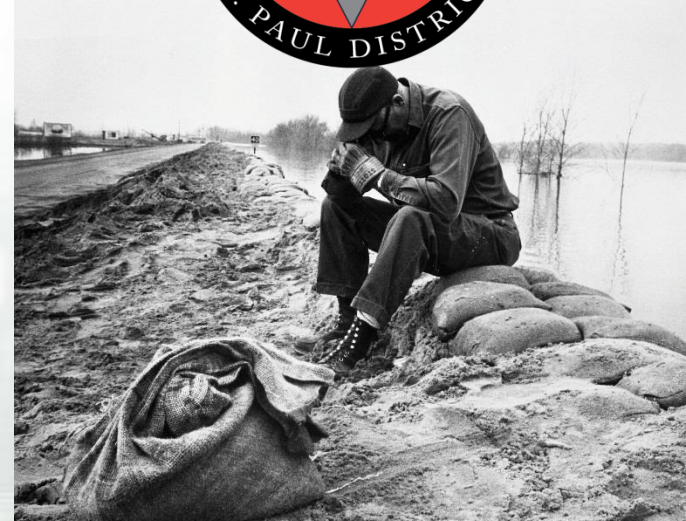
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US Army Corps of Engineers
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or to 1960, random tiling connected low areas



The NEW Wa

Project Facts

480 acres

196,000 linear
feet of tile

37 miles of til

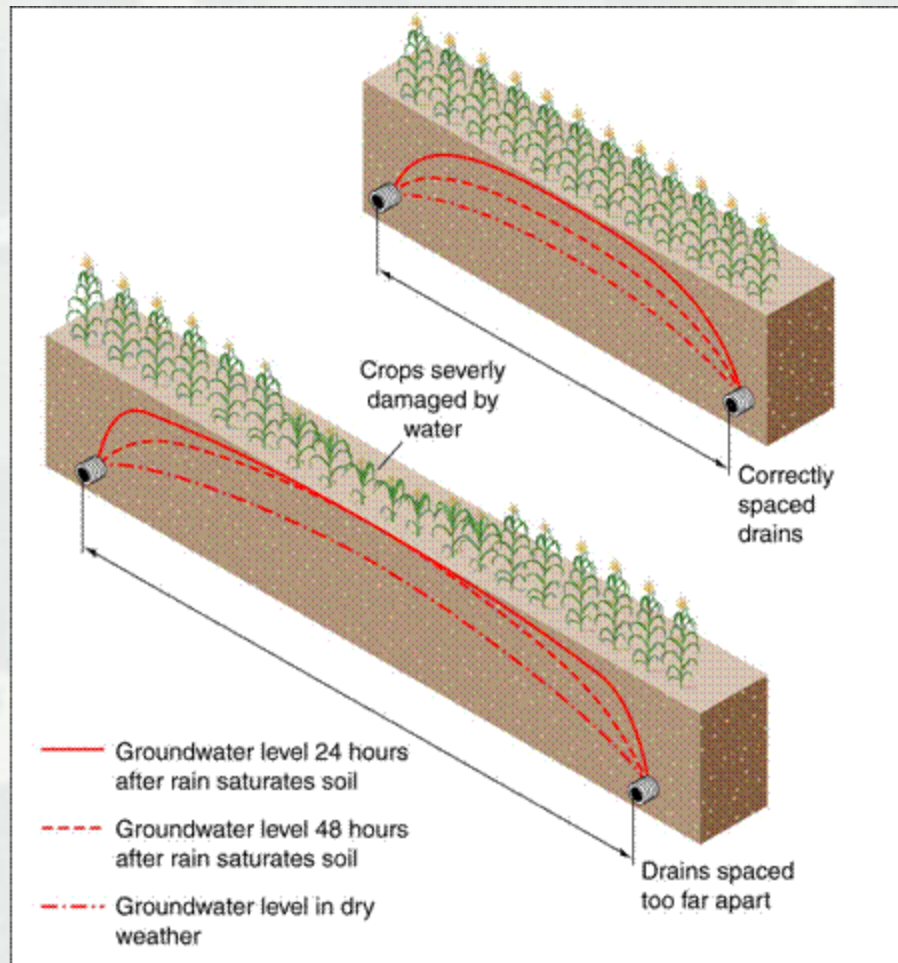


Figure 14. The effect of drain spacing upon groundwater level and crop damage.



Source: Illinois Drainage Guide



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Fate of Soil and Surface Water

1) Evaporate



2) Transpire



Depression Water

Surface

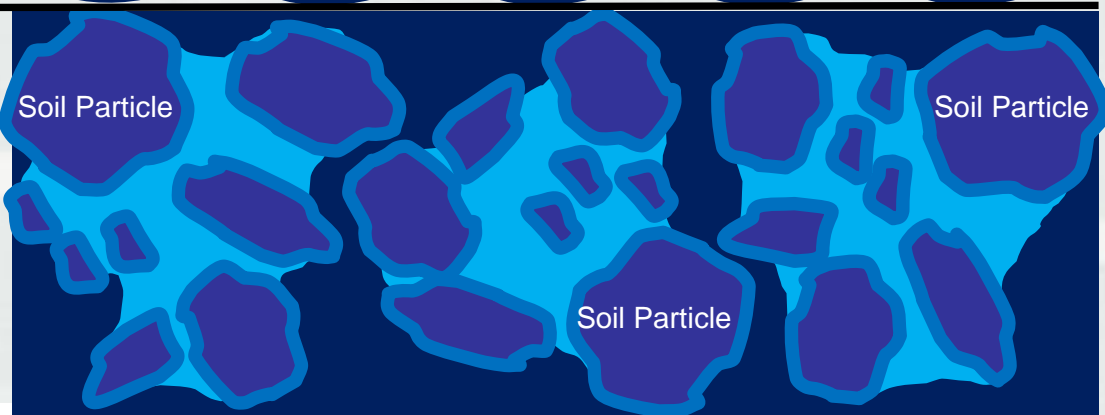
Drainable Water



Plant Available Water



Hygroscopic Water



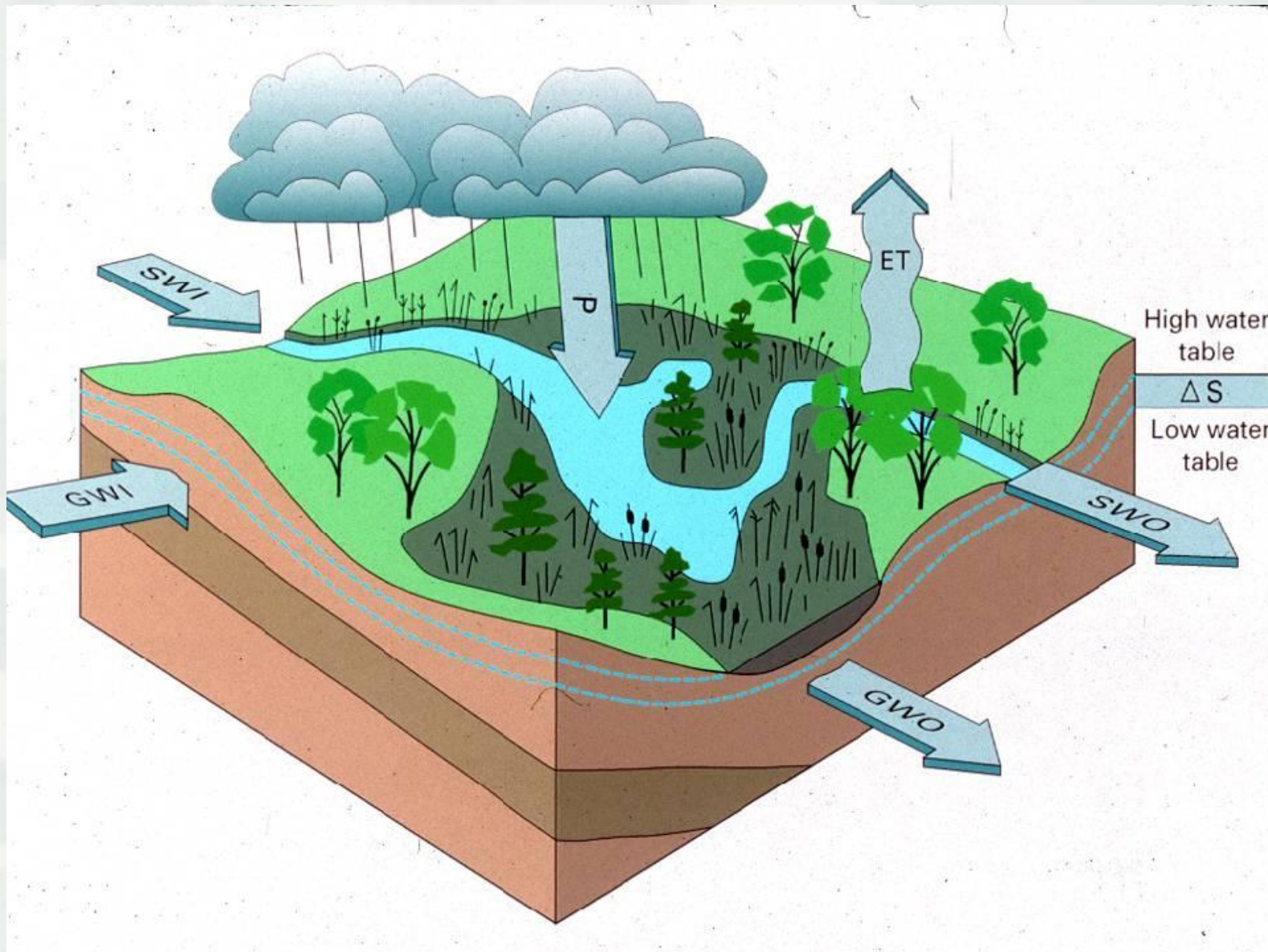
3) INFILTRATE



4) Drain via Tile



Office: BTSAC



Drainage

Anything that ***decreases*** the input or ***increases*** the output of water can cause a drainage impact

The challenge concerns determining if a decrease or increase is acceptable!!



Definitions:

Lateral Effect: or “LE”, refers to the distance to one side of a drain (drainage ditch or tile) that is drained to 1’ below the ground surface within 14 days time. It evaluates water table drawdown (the removal of soil gravitational water) and not the removal of surface water. See Figure 1 below.

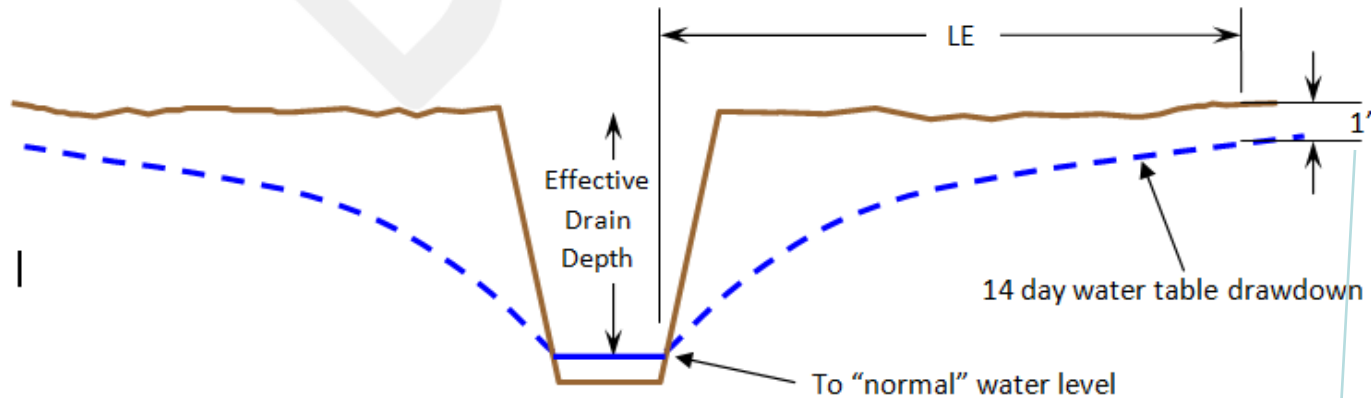


Figure 1: Lateral Effect (LE) and Effective Drain Depth

NOTE: At the LE, drainage is occurring! It is wrong to assume that drainage is zero at the LE.

- Resources Conservation Service (1997) to determine whether wetland hydrology is present.
- c. Estimate the effects of ditches and subsurface drainage systems using scope-and-effect equations (USDA Natural Resources Conservation Service 1997). A web application to analyze data using various models is available at http://www.wli.nrcs.usda.gov/technical/web_tool/-tools_java.html. Scope-and-effect equations are approximations only and may not reflect actual field conditions. The results should be verified by comparison with other techniques for evaluating drainage and should not overrule onsite evidence of wetland hydrology.
 - d. Use state drainage guides to estimate the effectiveness of an existing drainage system (USDA Natural Resources Conservation Service 1997). Drainage guides are available from NRCS offices or online (e.g., the Illinois drainage guide is available at <http://www.wq.uiuc.edu/dg/>). Cautions noted in item c above also apply to the use of drainage guides. In addition, Corps of Engineers district offices should be consulted for locally developed techniques to evaluate wetland drainage.
 - e. Use hydrologic models (e.g., runoff, surface water, and groundwater models) to determine whether wetland hydrology is present (USDA Natural Resources Conservation Service 1997).
 - f. Monitor the hydrology of the site in relation to the appropriate wetland hydrology technical standard (U.S. Army Corps of Engineers 2005).

van Schilfgaarde Equation

$$S^2 = \frac{9Kd_e(t - t_0)}{f} \left[\ln \frac{m_0(m + 2d_e)}{m(m_0 + 2d_e)} \right]^{-1}$$

S – drain spacing, or $S/2$ = lateral effect

d_e – effective depth from drain to impermeable layer

m_0 – initial water table height above drain

m – water table height after time t

t – time to drop water table from m_0 to m



f – drainable porosity

Notoriously difficult to obtain!

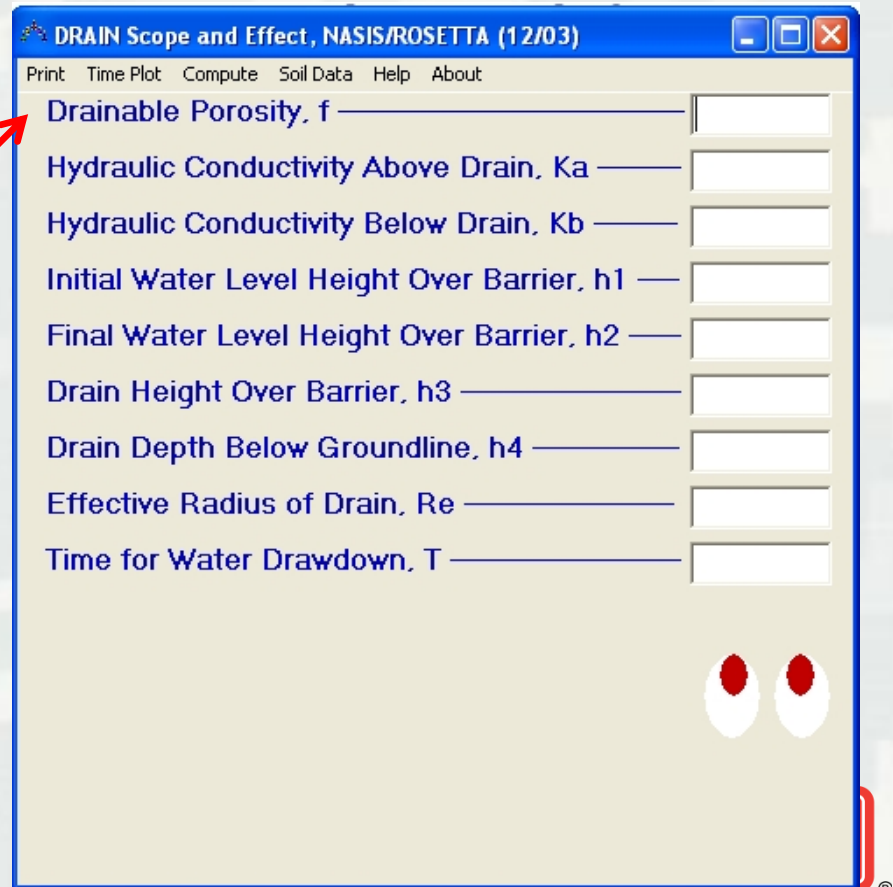


K – Saturated hydraulic conductivity

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ND- Drain program

- Run drainage equations using ND-Drain
- Lateral Effect
- Problem: Drainable porosity input
- Variable results



The screenshot shows the 'DRAIN Scope and Effect, NASIS/ROSETTA (12/03)' window. It has a menu bar with 'Print', 'Time Plot', 'Compute', 'Soil Data', 'Help', and 'About'. Below the menu bar are several input fields with labels and corresponding text boxes:

- Drainable Porosity, f —
- Hydraulic Conductivity Above Drain, K_a —
- Hydraulic Conductivity Below Drain, K_b —
- Initial Water Level Height Over Barrier, h_1 —
- Final Water Level Height Over Barrier, h_2 —
- Drain Height Over Barrier, h_3 —
- Drain Depth Below Groundline, h_4 —
- Effective Radius of Drain, R_e —
- Time for Water Drawdown, T —

At the bottom right of the window, there are two red circular buttons. A red arrow points to the 'Drainable Porosity, f ' input field.





Tools Comment

Fields for use in Wetland Determinations under the USDA Farm Bill

Wood County, Wisconsin

Mapunit Symbol	Mapunit Name	Component Name	%	LE Distance (Ft.) ¹ for Given Effective Drain Depth ²			
				2 Ft	3 Ft	4 Ft	5 Ft
SaB	Santiago silt loam, 2 to 6 percent slopes	Santiago	100	59	95	126	156
SaC	Santiago silt loam, 6 to 12 percent slopes	Santiago	100	N/A	N/A	N/A	N/A
SaD2	Santiago silt loam, 12 to 20 percent slopes, eroded	Santiago	100	N/A	N/A	N/A	N/A
SbB	Santiago silt loam, clayey substratum, 2 to 6 percent slopes	Santiago	100	52	81	105	129
Sh	Sherry silt loam	Sherry	100	38	57	74	90
Ss	Sherry stony silt loam	Sherry	100	43	64	83	102
Ve	Veendum silt loam	Veendum	100	N/A	N/A	N/A	N/A
Vs	Vesper silt loam	Vesper	100	46	70	90	110
WeA	Withee silt loam, 0 to 2 percent slopes	Withee	100	39	N/A	N/A	N/A
WeB	Withee silt loam, 2 to 6 percent slopes	Withee	100	39	N/A	N/A	N/A

1. Limitations: The Lateral Effect (LE) distances in this table do not apply for any of the following conditions (Scope and Effect JAA Level 3 is required for analysis of these conditions): (a) Ponding could occur on the site; (b) There is a potential for encirclement or interception by the drain; (c) The lateral effect distance is given as "N/A"; (d) The effective drain depth is > 5 feet

2. The Effective Drain (Ditch or Tile) Depth is the elevation difference (depth) between the ground surface at the approximate lateral effect distance and the "normal" water surface in the drain, or bottom of the drain if there is no "permanent" water.



Lateral Effect [WI NRCS]

The distance on each side of a tile or ditch in its longitudinal direction where the ditch or tile has an influence on the hydrology: that is acceptable to wetland regulators



Note: This is a plan view



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Wisconsin NRCS Drainage Tables

- COE project managers
- WI DNR wetland ID program staff (Tom Nedland POC)

WI NRCS does not provide drainage tables to the public, and do not provide technical support



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Technical Resources

[Conservation Planning](#)

[Data, Maps, & Analysis](#)

[Ecological Science](#)

[Engineering](#)

[Land Use](#)

[State Technical Committee](#)

Drainage Setbacks

The following documents may require [Acrobat Reader](#).

Drainage Setbacks Please choose County.

[Aitkin](#) [Anoka](#) [Becker](#) [Beltrami](#) [Benton](#) [Big Stone](#) [Blue Earth](#) [Brown](#) [Carlton](#) [Carver](#) [Cass](#) [Chippewa](#) [Chisago](#) [Clay](#) [Clearwater](#) [Cook](#) [Cottonwood](#) [Crow Wing](#) [Dakota](#) [Dodge](#) [Douglas](#) [Faribault](#) [Fillmore](#) [Freeborn](#) [Goodhue](#) [Grant](#) [Hennepin](#) [Houston](#) [Hubbard](#) [Isanti](#) [Itasca](#) [Kandiyohi](#) [Kittson](#) [Koochiching](#) [Lac qui Parle](#) [Lake](#) [Lake of the Woods](#) [Le Sueur](#) [Lincoln](#) [Lyon](#) [Mahnomon](#) [Marshall](#) [Martin](#) [McLeod](#) [Meeker](#) [Mille Lacs](#) [Morrison](#) [Mower](#) [Murray](#) [Nicollet](#) [Nobles](#) [Norman](#) [Olmsted](#) [Otter Tail](#) [Pennington](#) [Pine](#) [Pipestone](#) [Polk](#) [Pope](#) [Red Lake](#) [Redwood](#) [Renville](#) [Rice](#) [Rock](#) [Roseau](#) [Scott](#) [Sherburne](#) [Sibley](#) [Stearns](#) [Steele](#) [Stevens](#) [St. Louis](#) [Swift](#) [Todd](#) [Traverse](#) [Wabasha](#) [Wadena](#) [Waseca](#) [Washington/Ramsey](#) [Watsonwan](#) [Wilkin](#) [Winona](#) [Wright](#) [Yellow Medicine](#)

[Setback Distance Factsheet \(PDF; 0 KB\)](#)

[Setback Distance Worksheet \(PDF; 0 KB\)](#)



Setback Distances in feet
 Meeker County, Minnesota Table date: October 30, 2012

Map Unit Symbol	Drain Depth, feet			
	2	3	4	5
35	80	120	160	190
85	60	90	110	130
86	50	60	70	90
112	50	50	60	70
113	50	60	70	90
114	50	60	70	90
129	110	210	290	350
130	50	60	80	90
134	50	60	80	100
136	60	90	110	130
140	60	90	110	140
178	100	180	210	270
181	110	160	230	260
183	110	190	250	320
197	60	90	120	140
211	50	70	80	100
229	50	70	90	100
239	50	50	70	80
281	90	150	200	250
399	100	170	220	280
415	200	330	400	400
423	50	70	80	100
511	70	110	140	180
523	50	60	80	100
525	50	70	140	170
539	50	70	90	120
548	50	150	240	380
610	60	80	110	130
613	90	140	180	220
664	50	60	80	90
740	50	60	70	80
899	50	50	60	70
956	50	60	80	90
978	50	60	70	80
1015	120	210	280	340

Notes: 1) These setback distances are only for the situation where a drainage system will be installed and the landowner wishes to avoid impacting the wetland hydrology. 2) These values assume the ponded water on the site is 0.25" or less. 3) The effective depth of the drain (ditch or tile) is the elevation difference between the ground surface at the approximate setback distance and the water surface in the drain, or the bottom of the drain if it typically has no standing water.



Ca-carbonate	28	20 - 30
Soil color chroma	28	15 - 50
Depth to carbonates	30	20 - 49
Cation exchange capacity	32	20 - 40
Depth to mottling	35	20 - 50
Organic matter content	39	20 - 61
Plasticity index	41	20 - 63
Soil thickness	43	25 - 58
Exchangable Ca	48	30 - 73
Exchangeable K	57	7 - 160
Exchangeable Mg	58	31 - 121
Water-soluble salt extract	48	
Hydraulic conductivity	75	13 - 150

Most variable

Hydraulic conductivity is an extremely variable soil property!

Generally, the spatial variability in soils increases with the nature of the parent materials in the following order (Drees and Wilding, 1973):

[glacial till](#) [glacial outwash](#) = [glacial lacustrine sediments](#) = [alluvium](#) [pyroclastic and tectonic rocks](#) [drastically disturbed materials](#)

Drainable Porosity and Texture

- Sands have large pores, high hydraulic conductivity and large drainable porosities
- Clay soils have small pores, low hydraulic conductivities and low drainable porosities
- For an equal amount of water drained, a sandier soil will show a lower water table drop than a soil with higher clay content



Soil Structure

- Soil structure can modify texture and can—for example- introduce significant macroporosity into fine textured soils



Different Water Holding Capacities

- Sands have low water holding capacity; plants wilt quickly as the water table drops
- Mucks have high water holding capacity and plants can persist longer as the water table drops



History of Lateral Effect Guidance

- Discussions began in 2005 to develop interagency guidance
- Opted to let NRCS take the lead—they are the recognized experts and a comparable alternative methodology did not exist
- NRCS, Minnesota and Wisconsin, issued their county-based guidance in 2013
- BWSR Guidance (and a similar CORPS Standard Operating Procedure) **adopts the NRCS number** and adds to the NRCS guidance



Purpose of COE/BWSR guidance

- Companion to NRCS setback/LE tables
- Supplemental info on background & assumptions
- A tool for wetland managers and regulators to assess impacts
- Improve consistency

http://www.bwsr.state.mn.us/wetlands/delineation/Drainage_setback_guidance.pdf



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The van Schilfgaarde
equation cannot
accommodate significant
surface water.



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A drainage prediction from the van Schilfgaarde equation assumes a drainage contribution from other drains in the system. So, a single drain has less drainage impact than a drain in a drainage system.



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1.Drainage equations produce optimum results when used with drain depths between 2 and 5 feet.

2. A drain must have at least 12 inches of depth before it is considered to have an effect on the water table

3.Drainage predictions for drain depths greater than 5 feet are problematic as NRCS soils data becomes limited at depths greater than 5 feet and the weight of the overlying soil at depths greater than 5 feet generally decreases hydraulic conductivity.



Drainage equations were set up to predict water flow through mineral soils. Organic soils have different water retention and dewatering qualities which require significant modification of drainage equations to produce reasonable results.



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There is no allowance in drainage equations for water flow across the barrier. Where groundwater is constantly replenishing the system, predicted drainage effects will be less.



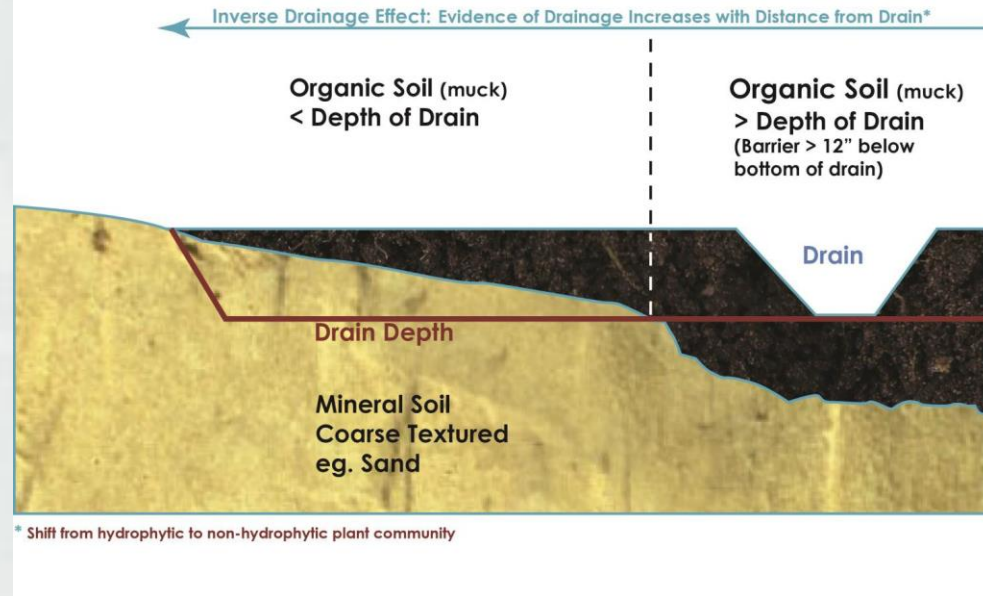
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To meet the predicted drainage effect, the drain must convey the water removed from the soil profile. If the drain does not convey water, drainage effect is minimal.



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Figure 6



Lateral Effect versus Volume of Discharge

- Note: Grade is not a factor in drainage equations
- Of the factors used in drainage equations, depth of drain and hydraulic conductivity (related to soil characteristics) are key in determining drainage effect
- Size and grade of drain are key in determining capacity for volume of discharge



Sizing Considerations

Tile Diameter	Grade = 1%	Grade = 3%
4 inch single wall corrugated plastic	74 gallons per minute (gpm)	128 gpm
8 inch single wall corrugated plastic	471 gpm	816 gpm

NRCS (MN and WI) drainage tables were developed using tile parameters and are also applicable to ditches. On average, a comparable size ditch has about a 4 percent greater drainage effect than a tile. This is assumed to be a minor difference.



More About Size and Depth

- Other factors being equal:
 - compared to a 4 inch tile, an 8 inch tile has less than 10 feet more lateral drainage effect (i.e. negligible!!)
 - doubling the depth of a drain causes significant increases in lateral effect; in some cases, more than a 2X increase



Drainage tables are no panacea

- Surface water diversions
- Encirclement
- Volume considerations in ditch maintenance



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Swift County

Red = tile

Blue = wetland

Water source to
wetlands



Tile outlet into ditch



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When to use the tables

- Assess loss of wetland hydrology via tile or ditch
- Determine setback to minimize impact to wetland hydrology
- Potential wetland restoration



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If the water remains!

Hydrology may exist when a drain is present for various reasons:

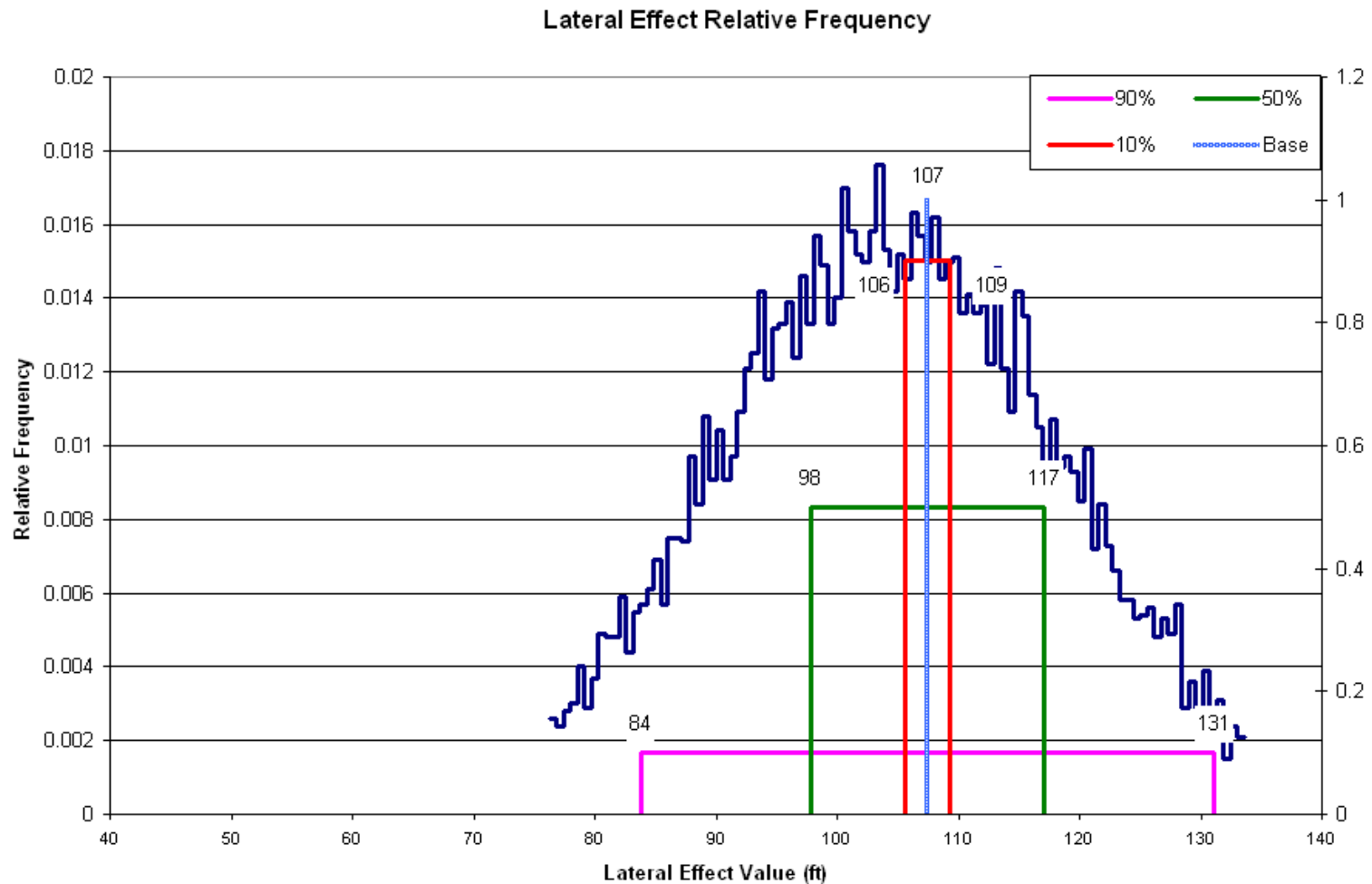
- Soil type, particularly organic soils
- Depth of drain with respect to barrier
- Wetland water budget—Source of water
- Effectiveness of drain



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Relative Accuracy of Drainage Estimates

Source: Dr. Joel Peterson, UW-RF



Take home messages

- Setback values are institutionally accepted & provide a consistent number
- Guidance uses best available information
- Okay to use drainage equations as a **piece** of information
- Do NOT argue over several feet !!!

AND



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Final Take Home

- Incorporate data such as historical photographs, hydrology indicators and other wetland delineation techniques
- Refine soil map
- Monitor water table—IF NECESSARY



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